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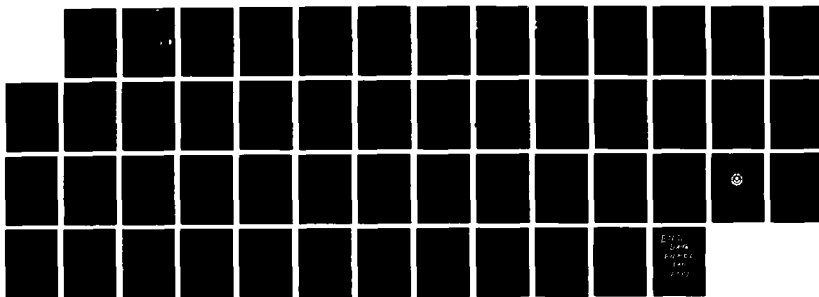
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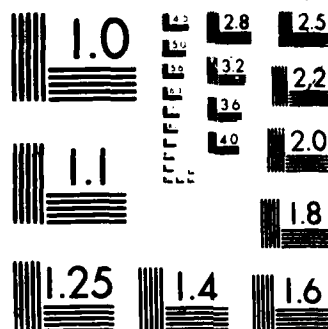
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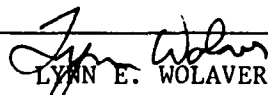
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A REVIEW OF THE QUALITY AND SAFETY OF IRRADIATED FOOD

A Monograph

Presented to the Faculty of the Graduate School

of Cornell University

in Partial Fulfillment of the Requirements for the Degree of

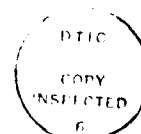
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James Herbert Cox, Jr.

May 1987



## BIOGRAPHICAL SKETCH

James Herbert Cox, Jr. was born on March 24, 1952 in Shreveport, Louisiana. He graduated in 1970 from Rincon High School in Tucson, Arizona and attended the University of Arizona for two years. After transferring to the University of Arkansas, he received a Bachelor of Science degree in Business Administration in May 1975 and was commissioned as a Second Lieutenant in the United States Air Force.

After a temporary tour of duty in the Air Force, he was employed in various unit management positions with Morrison's Cafeterias in Alabama, Mississippi and Tennessee. Recalled to active duty by the Air Force in 1979, he has served continuously since then. He has held positions as Food Service Officer, Officer's Club Manager, and Squadron Operations Officer at Minot Air Force Base, North Dakota; and Food Service Staff Officer and Information Systems Staff Officer at Headquarters, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida. In 1985, Captain Cox was selected by the Air Force Institute of Technology to attend the School of Hotel Administration at Cornell University to obtain a Master of Professional Studies degree.

He is married to Kimi Lea Green of Texarkana, Arkansas. They have four children: Renda, Carrie, Joel, and Craig.

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Special thanks also to Bonnie Richmond of the Hotel School faculty for her guidance and support in helping me to complete this major undertaking.

Finally, and most importantly, my special thanks to my wife Kimi, and my children Renda, Carrie, Joel, and Craig, for supporting me during this time at Cornell, especially while I researched and wrote this monograph. I hope I can make up to them all the time together we have lost in the past two years.

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## INTRODUCTION

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In 1985 and 1986 the United States Food and Drug Administration (FDA) took bold steps to broaden the number of food products approved for irradiation and subsequent human consumption. In the twenty years prior to this action, irradiation had been approved for wheat, wheat products, and white potatoes but the process was never used commercially. A controversy about food safety and quality has resulted from the FDA's action because the approval was based on only 5 of the more than 413 studies completed on the subject (Savagian, 1986).

Legislation has been introduced in the Congress and in several state legislatures to restrict the use of this process or require some type of labeling. Consumer concern about the safety and quality of irradiated food has important implications to a multi-million dollar foodservice industry. An alarmed or concerned public may not accept irradiated products, despite FDA assurances that they are safe.

— This monograph will begin by describing the food irradiation process and summarizing its historical development as a way to prolong the shelf-life of food and prevent the spread of foodborne illness. Food irradiation is an increasingly important issue in a world where: food spoilage has reached phenomenal

proportions, millions of people are going hungry, many chemical protective and preservation agents have been banned, and the energy costs of other food processes are becoming prohibitively expensive.

This historical discussion will be followed by an examination of the known effects of irradiation on food quality. Included will be a presentation of the effect of irradiation on the flavor, appearance, and smell of food. The nutritional adequacy of irradiated foods and several improvements in some foods caused by irradiation will also be discussed.

Finally, a research paper on food irradiation would be incomplete without a discussion of the safety issues associated with the process and its products. The safety of irradiated foods is an issue of growing concern to the American public. While irradiation shows great potential for reducing foodborne illness, the formation of radiolytic products, the physical dangers of radiation, and the possibility of cancer or genetic mutation worries many people. The labeling issue is an outgrowth of this public concern. The uncertainty and fear of irradiation is largely caused by ignorance and misunderstanding of the process and its effect on food.

## WHAT IS FOOD IRRADIATION?

Food irradiation is the process of exposing food products to some form of ionizing radiation for the purpose of prolonging shelf life or reducing the threat of foodborne illness. A small amount of radiation can kill insects and microorganisms that cause spoilage or can damage microorganisms genetically so they can no longer reproduce. In addition to extending a products shelf life, irradiation can also disrupt cell division to slow ripening in fruits and vegetables. The food itself does not become radioactive. During irradiation, radiation passes directly through food without being absorbed.

Three types of radiation are used in food irradiation: gamma, X-ray, and electron. Gamma radiation is electromagnetic radiation of short wavelength with no electrical charge but deep penetrating ability. It is continuously emitted by such sources as radioactive cobalt and cesium. X-rays are also a type of electromagnetic radiation of short wavelength. They are machine produced without electrical charge and have deep penetrating ability (Food Technology, 1983). Figure 1 indicates where the different types of electromagnetic radiation are on the electromagnetic spectrum. Gamma and X-ray radiation have slightly higher frequencies than the more commonly

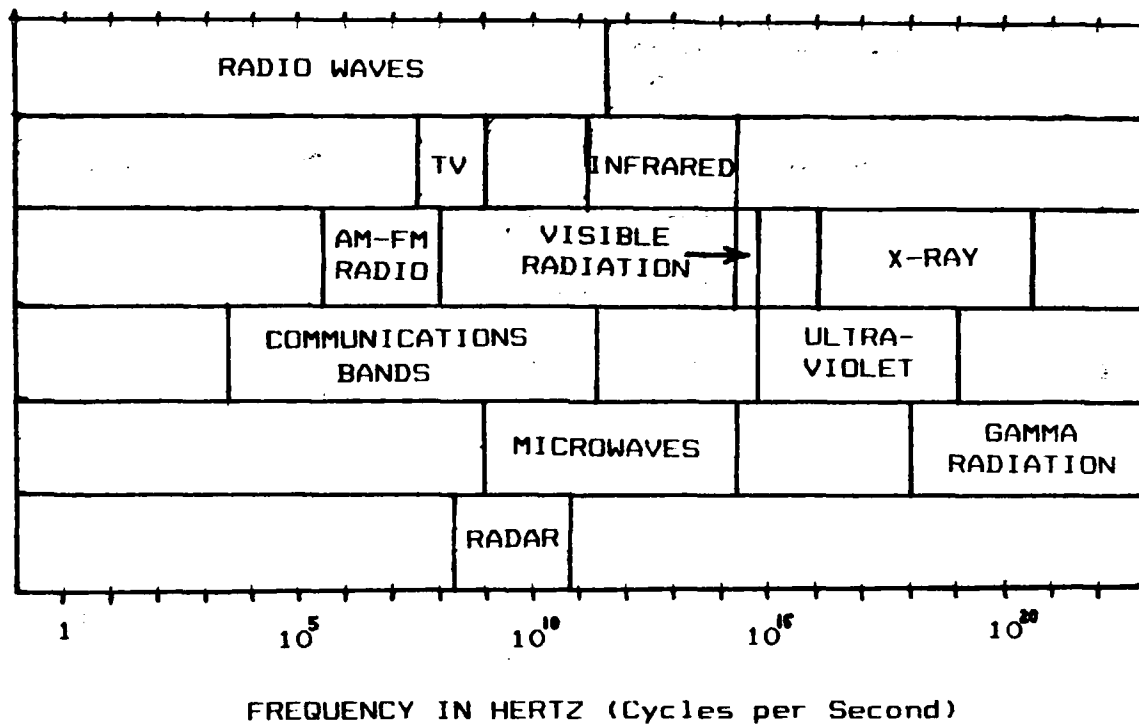


Figure 1: The electromagnetic spectrum indicating the range and relative positions of different types of radiant energy (Coon, et al., 1985).

understood types of radiation (radio, television, visible, microwave, etc.). Not shown is accelerated electron particles, the third type of radiation used to irradiate food.

Electron radiation differs from the other two types of radiation because it consists of negatively charged electron particles accelerated by linear accelerators to very high speeds and energy levels. The penetrating ability of electron radiation is limited and is directly proportional to its energy level. Electrons accelerated to about 10 million electron volts, for instance, only have enough energy to penetrate a food product an inch or two (Food Technology, 1983).

Food irradiation is considered a 'cold' process because it uses no heat (Edmundson, 1986). As a result, the chemical composition of the radiated food is not changed. Irradiation is considered a physical process by scientists and most countries in the world. Since 1958 the FDA has classified it as a food additive. As a result, its use is more regulated than other food preservation processes, such as thermal canning or freezing.

Food irradiation is classified in two ways using the amount of radiation applied. This is called the dose level. The most frequently used method refers to three different dose levels: low, medium, and high. Dose is generally measured in kilorads (krads) or

kiloGrays (kGys), which are measurements of a unit of energy absorbed from ionizing radiation per unit of mass of the irradiated material (Zurer, 1986). One kiloGray is equal to 100 kilorads.

Low-dose (pasteurizing) applications are generally used for insect control, to delay ripening of fresh produce, and to inhibit sprouting in certain types of vegetables. Any dose less than 1 kiloGray (100 krad) is classified as low dose. Dose levels between 1 and 10 kiloGrays (100 to 1000 krad) are considered medium dose. This level is used to prolong product shelf life and to reduce the amount of microbial pathogens present in food products. Any dose higher than 10 kiloGrays (1000 krad) is labeled a high dose and can be used to sterilize food products, thus eliminating microbial pathogens and viruses. With proper packaging and storage temperatures, food products subjected to high doses become shelf stable and can be stored for long periods of time. Figure 2 summarizes each dose level and its primary application.

An earlier method of classification not used as often today is also based on the irradiation dose but incorporates the effect on microbe levels as well. The term 'radurization' is used to describe the radiation exposure needed to reduce the level of certain organisms that cause food spoilage. 'Radicidation' is the dose necessary to reduce various pathogenic organisms below

<u>Dose Level</u>	<u>Application</u>
Low Dose (Below 1 kGy)	<p>Inhibit sprouting of potatoes, onions, and garlic</p> <p>Inactivate trichinae in pork</p> <p>Kills or prevents insects from reproducing in grains, fruits, and vegetables</p> <p>Delays ripening of certain fruits</p>
Medium Dose (1-10 kGy)	<p>Delays spoilage of meat, poultry, and fish by reducing spoilage microorganisms</p> <p>Reduces salmonella and other foodborne pathogens in meat, fish, and poultry</p> <p>Extends shelf life by delaying mold growth on strawberries and some other fruits</p>
High Dose (Above 10 kGy)	<p>Sterilizes meat, poultry, fish, and some other foods</p> <p>Kills microorganisms, viruses, and insects in spices and seasonings</p>

Figure 2: Food irradiation doses and applications (Zurer, 1986).

detectable levels. Finally, 'radappertization' is the high dose treatment used to completely sterilize a food product and make it shelf stable. Both methods of classification can be and are used interchangeably to describe food irradiation.



## DISCOVERY AND DEVELOPMENT OF FOOD IRRADIATION

The discovery of X-rays and radioactivity in the mid-1890s opened many possibilities for the use of the mysterious and invisible properties of radiation. One potential use of radioactivity was as a method to prolong the shelf-life of perishable food supplies. The first U.S. patent for the use of X-rays to kill microorganisms in meat was obtained in 1921 (Goresline, 1982). This was followed by a 1930 French patent for the preservation of food by irradiation (Goresline, 1982). Additional experimentation concluded in 1936 revealed that X-rays could be used to inhibit vegetable sprouting (Matsuyama and Umeda, 1982). Widespread experimentation and interest in the potential of food irradiation did not occur until after the outbreak of World War II.

Interest in irradiation increased during World War II with the development of very powerful electron generators which made additional experimentation easier and more controllable. This was followed by the 1947 publication of a paper by Drs. Brasch and Huber of the Electronized Chemicals Corporation of New York which made bold claims about the potential use of such equipment in the food industry (Hannan, 1956). Their studies compared the different effects of short and long-term radiation exposure and identified different

methods that could be used to reduce or eliminate various side effects which might affect the taste, odor, and/or appearance of irradiated products.

Additional studies continued into the early 1950s by scientists at major universities including the Massachusetts Institute of Technology, the University of Michigan, and Columbia, as well as private companies such as General Electric, Metropolitan-Vickers, Swift and Company, and American Can (Hannan, 1956). These widespread and independent studies produced valuable insights into the potential of food irradiation yet lacked the focus and resources necessary to take the research much further. This would come with government and military interest and involvement in food irradiation research.

## DEVELOPMENT OF A NATIONAL FOOD IRRADIATION PROGRAM

Throughout the 1940s and 1950s, U.S. government involvement in food irradiation study was minimal. In fact, as late as 1951, the Department of Agriculture and the Army Quartermaster Corps refused monetary assistance to the Electronized Chemical Corporation, contending that private enterprise should pay for commercial development of food irradiation processes (Goresline, 1982). Despite this setback, interest in radiated foods continued to grow in private industry and in government agencies such as the Navy and the Atomic Energy Commission (AEC). The AEC was seriously looking for ways to utilize the waste fission products beginning to accumulate from the American nuclear industry; Navy interest was in reducing refrigerated storage space on its ships (Gardner and James, 1957).

Since the Army Quartermaster Corps was the Department of Defense agency with overall responsibility for subsistence research and development for the Department of Defense, a feasibility study was conducted to determine what role, if any, the Army should take. The study concluded that the acceptability of military field rations could be improved with the successful development of radiation food processing and recommended a lead role for the Army (Goresline, 1982).

Based on this study the Army General Staff implemented a 10-year, multi-million dollar food irradiation research and development program in 1953. As part of this program, the Army constructed a food radiation facility at its Natick Research and Development Laboratories in Natick, Massachusetts. This facility conducted and/or coordinated much of the subsequent research in food irradiation.

In 1960, the AEC joined the Army irradiation program. The Army focused attention on high dose irradiation of meat and poultry products while the AEC concentrated on low dose pasteurization of fish, fruits and vegetables. This research eventually led to FDA approval for human consumption of certain irradiated products. In February 1963 high-dose irradiation was approved for sterilizing canned bacon. The following August a lower dosage was approved to control insect infestation in wheat and wheat flour. In June 1964 approval was extended to white potatoes to inhibit sprouting. These items were never commercially irradiated because less expensive methods of preservation were available and were more socially acceptable to consumers.

While efforts by the Army to improve military field rations kept irradiation programs alive during the 1960s, a need by the Air Force for foods suitable for high altitude feeding gave new purpose and direction to

U.S. irradiation programs in the 1970s. The foods and methods developed to meet this need evolved into the first foods used in the space program. Irradiated foods eventually became an attractive alternative to freeze-dried food products. While Soviet cosmonauts were the first to take irradiated food into space, the first American use of irradiated food was on Apollo 12 in 1969 (Goresline, 1982). Each subsequent mission, including the Space Shuttle, has carried new and improved irradiated foods into space. Many of these products were the prototypes of irradiated food products approved, or awaiting approval, by the FDA.

In 1982, the U.S. Department of Agriculture (USDA), with support from the Department of Energy (DOE), assumed supervisory jurisdiction over all U.S. irradiation programs. Irradiation began the transition from an experimental phase to an implementation phase. The road to commercial irradiation in the U.S. was to remain a slow and arduous one accompanied by much controversy. Elsewhere in the world acceptance of food irradiation was growing.

## INTERNATIONAL FOOD IRRADIATION EFFORTS

The interest in food irradiation by the United States did not go unnoticed by the rest of the world. On December 8, 1953, President Eisenhower outlined his 'Atoms for Peace' program to the United Nations (Goresline, 1982). This speech heightened interest in the peaceful uses of nuclear energy. Many countries were interested in improving their food supplies and reducing losses due to spoilage and contamination. Some of these countries initiated or expanded their own food irradiation programs.

Potatoes became the first irradiated food item approved for human consumption in any country. They received clearance by the government of the Soviet Union in 1958. The first irradiation pilot plant in the world was built in the Soviet Union in 1964 (Goresline, 1982). By 1975, the number of pilot plants around the world had grown to 70 and national irradiation policies existed in at least 43 different countries (Goresline, 1982).

In the late 1950s and early 1960s, the United Nations began to play an increasingly important role in irradiation research through sponsorship of conferences and symposiums designed to encourage the exchange of information between member nations. As experimentation continued and new insights were made, the list of food products approved for use at some level of irradiation

dose grew at a steady, methodical pace. Current estimates of the number of irradiated products approved for consumption exceed 40 in at least 24 different countries (Skala, et al., 1987).

Both developed and developing countries around the world have continued their interest in the technology and potential of food irradiation. Figure 3 lists the countries that have already developed or are now developing commercial irradiation facilities. Despite the international progress made in irradiation and irradiation technology, countries around the world continue to look to the U.S. and to FDA approvals as a benchmark for safety.

**Countries with  
Operational Facilities**

United States  
Brazil  
Chile  
Belgium  
Netherlands  
East Germany  
Hungary  
Israel  
South Africa  
Soviet Union  
Japan  
Taiwan

**Countries with Facilities  
Planned or Under Construction**

Mexico  
France  
Italy  
Poland  
Bulgaria  
Ghana  
Nigeria  
Pakistan  
Bangladesh  
Sri Lanka  
Thailand  
South Korea

Figure 3: Countries in the world with irradiation facilities in operation, under construction, or planned (Zurer, 1986).



## RECENT DEVELOPMENTS IN FOOD IRRADIATION

In late 1980, a Joint Expert Committee on the Wholesomeness of Irradiated Foods was convened by the World Health Organization and the International Atomic Energy Agency. After reviewing the results of major food irradiation studies and developing a better understanding of the changes occurring in irradiated foods, the committee determined that foods irradiated at doses below 10 kGys (1000 krads) were safe and should be approved for human consumption without additional testing. The committee also classified food irradiation as a physical process, not a food additive, and advised that labeling was not necessary (Josephson, 1983).

In 1981, the FDA first proposed a new policy on irradiated food that would give blanket approval to any food irradiated at doses less than 1 kGy (100 krads). It also proposed additional approval for products irradiated at doses between 1 kGy (100 krads) and 10 kGys (1000 krads) after successful 90-day animal feeding studies and tests for mutation and radiolytic products. The FDA further proposed allowing spices to be irradiated at doses as high as 25 kGys (2500 krads).

In July 1985, the FDA formalized this proposal and approved the irradiation of pork to control growth of trichinae. Additional approval was given in April 1986 allowing the irradiation of fruits and vegetables and

increasing the radiation dose allowed for dried herbs, spices and vegetable seasonings. Additional approvals for other products are pending, with irradiation of chicken for control of salmonella as the next likely product to be approved for irradiation. However, FDA approval of irradiation for a particular item does not mean it will be immediately irradiated commercially.

## STATUS OF COMMERCIAL IRRADIATION IN THE U.S.

While countries around the world are gradually expanding their use of irradiated foods, the level of food irradiation in the U.S. remains at very low levels. The only products being commercially irradiated are bulk spices, but less than 1 percent of the spices consumed in the U.S. in 1985 were irradiated (Steyer, 1986). The major food production companies are practically fighting to be the last company to introduce irradiated products. Market research indicates that consumers are "not necessarily unwilling to try irradiated products; they're simply unsure and uninformed" (Steyer, 1986). As Tony Adams, the Director of Marketing Research and Planning for the Campbell Soup Company put it, "...a lot of pioneers were shot by the Indians" (Steyer, 1986).

Irradiation has been successfully used in some hospitals to sterilize meals for patients with poor immune systems and extreme susceptibility to infections. The Fred Hutchinson Cancer Research Center in Seattle has had such a program since 1969 (Aker, 1984). Food irradiated at high sterilizing doses allows patients undergoing certain therapies or with diseases that suppress the immune system to have safe, bacteria-free meals. This type of small, successful application of irradiation technology helps open the door to eventual

commercialization and consumer acceptance of food  
irradiation even though questions about the quality and  
safety of irradiated food products continue.

## EFFECTS OF IRRADIATION ON FOOD QUALITY

### Appearance, Flavor and Smell

Early experimentation with food irradiation produced products that were undesirable in appearance, flavor and smell. These products were off-colored, blemished, easily damaged, or unappetizing in appearance. For example, irradiating fresh produce often produced softening, rot, blackening, sensitivity to injury, and uneven ripening. Unusual off-flavors and odors were prevalent in many products. A "wet dog" odor was a frequent description of many irradiated meat products tested in the 1950s (Takeguchi, 1983). Dr. Nell Mondy, a Food Nutritionist and Professor at Cornell University, was a participant in taste panels of irradiated foods while a graduate student in the 1950s. She describes the taste and texture of irradiated meats as "awful" and the odor as even worse--"rancid and putrefied" (Mondy, 1986).

As research became more sophisticated, new techniques were developed which:

- 1) combined irradiation with partially/fully cooked foods or hot water baths;
- 2) varied the temperature of the product being irradiated;
- 3) controlled oxygen contact with foods during and after irradiation;

- 4) changed the moisture levels within or around the food product during irradiation;
- 5) varied the storage conditions of irradiated products; and
- 6) adjusted the dose levels to which food products were exposed.

These new techniques made it easier to minimize undesirable reactions in irradiated food, improving overall quality. In time, the best dose level and most desirable physical/environmental conditions for each food product can be determined. Two recent studies involving irradiated California navel and valencia oranges identified the approximate dose each orange type could be irradiated before changes in product quality could be detected by trained and untrained judges (Nagai and Moy, 1985; O'Mahony, et al., 1985).

Determining proper dose levels is the key to successful and effective irradiation. The enormity of this task is phenomenal considering the thousands of different food products commercially available in the U.S. and the number of possible combinations of dose, temperature, moisture level, storage conditions, cooking level, and atmospheric exposure for each item. While it may be impossible to eliminate all changes in flavor, texture and odor, these changes can be controlled and minimized. It is also important to remember that these

changes occur when food is cooked, frozen or canned. The same can be said of changes in nutrient content.

#### Nutritional Adequacy

According to the FDA, scientific experimentation has indicated that there are no nutritional differences between food that is not irradiated and food irradiated at levels below 1 kiloGray (Lecos, 1986). Many studies have looked at the problem of destruction or alteration of nutrients by the irradiation process and affirmed this statement. Carbohydrates, lipids, proteins and amino acids undergo very few changes as a result of irradiation (Skala, et al., 1987). The vitamins thiamine and pyridoxine, while very susceptible to processing loss during irradiation, are no more so than they are with other processing methods. Figure 4 summarizes the changes in thiamine and pyridoxine content of certain radappertized meats identified in a recent study conducted by the Army (Skala, et al., 1987). They indicate:

- 1) that gamma irradiation causes less thiamine loss than thermal processing;
- 2) that electron particle irradiation causes less thiamine loss than either thermal processing or gamma irradiation; and
- 3) that pyridoxine loss in all three treatments is 50 percent or less.

<u>Meat</u>	<u>Vitamin</u>	<u>Type of Treatment (% Loss)</u>		
		<u>Gamma</u>	<u>Electron</u>	<u>Thermal</u>
Chicken	Thiamine	74	34	78
Beef	Thiamine	77	56	79
Chicken	Pyridoxine	50	38	17

Figure 4: Changes in the levels of certain vitamins in different meats irradiated at high doses (Skala, et al., 1987).



### Other Improvements

Several improvements to specific foods have been documented in assorted studies conducted on food irradiation. The loaf size of bread made from irradiated wheat is larger than bread made from nonirradiated wheat. Irradiation also appears to have a tenderizing effect on beef. Dehydrated fruits and vegetables require less rehydration time after irradiation. Gas producing sugars in beans are reduced, as is cooking time. Red wines age faster when subjected to ionizing radiation. Nitrite levels in bacon can be lowered when it is irradiated (Morrison, 1986).

## SAFETY OF IRRADIATED FOOD

### Foodborne Illness

The prevention of foodborne illness is one of the most important benefits to evolve from food irradiation. The incidence of foodborne illnesses is on the rise. Public health officials estimate that the nation's two most common food-related illnesses--salmonellosis and campylobacteriosis--afflict more than 4 million people each year (Roberts, 1986). In the last 16 years alone, the annual number of reported cases of salmonellosis has doubled and the USDA states that, on the average, a staggering 35 percent of all poultry sold to the public is infected with salmonella (Sawyer, 1987).

A recent study by the Economic Research Service of the USDA estimated that the annual cost in illness and death resulting from campylobacteriosis from chicken, salmonellosis from chicken and beef, and toxoplasmosis from pork is approximately \$1 billion in medical costs and lost wages (Roberts, 1986). When the cost in lost sales by food processors and restaurants, product recalls, plant closings, and liability suits associated with the outbreaks of foodborne illness are included, the total costs of these three illnesses rises to about \$2 billion in the U.S. alone (Roberts, 1986).

Irradiation can be a very effective tool for preventing the spread of these diseases in the national

food supply. According to Alan R. Post, Special Assistant to the Deputy Administrator of the Food Safety and Inspection Service at the USDA, interest by the USDA is in "...ensuring that food products are safe and wholesome" (Zurer, 1986). Irradiation is a superior tool for controlling salmonella and other dangerous foodborne pathogens. Pork irradiation can prevent human toxoplasmosis and trichinosis. Proper levels of irradiation could virtually eliminate campylobacteriosis and salmonellosis from chicken. Beef irradiation at sufficient levels could destroy salmonella and tapeworm.

One area still under study by the FDA involves bacteria which can form endospores and highly dangerous toxins or can mutate into radiation-resistant bacteria. *Clostridium botulinum*, for example, is very resistant to irradiation. The danger is that spoilage bacteria would be killed by high dose irradiation, leaving the more dangerous *Clostridium botulinum*. Normally, spoilage microorganisms produce a foul, decayed odor as they grow that keeps people from eating the contaminated food. But as George H. Pauli, Chemist and Supervisory Safety Officer in the FDA Center for Food Safety and Applied Nutrition explained, "With the spoilage bacteria destroyed...there would be no clue that the fish or chicken or whatever may contain harmful microbes." (Zurer, 1986). This is probably why the FDA has

proceeded with such caution in approving irradiation doses over 1 kGy (100 krads). At lower doses this is not a problem since few microbes are killed.

The FDA concedes that under certain conditions mutant microorganisms could form in irradiated foods. It also maintains that mutant microorganisms, such as bacteria, can occur naturally and the likelihood of them becoming resistant or more harmful is very remote (Steyer, 1986). Several studies conducted in India have linked irradiation to an increase in the production of molds that produce cancer-causing mycotoxins. The FDA maintains that these studies did not duplicate normal food handling practices and the results cannot be blamed on irradiation (Steyer, 1986).

#### Free Radicals

Irradiation leaves no residue or hazardous radiation in food, but like other methods of food processing, slight chemical changes do occur. New substances called radiolytic products--or 'free radicals'--are formed. The formation of radiolytic products in irradiated food has been a major issue of concern to consumers, consumer groups, and the FDA. Free radicals result from the splitting of water into hydrogen, hydroxyl radicals, and hydrated electrons. These generally recombine to form water and hydrogen peroxide but can sometimes combine with other components of food to create secondary radicals. Where

water is minimal, as in fats, free radicals form directly from triglycerides (Zurer, 1986). Few of these radiolytic products are particularly unique to irradiated foods. About 90 percent of radiolytic products are natural components normally present in food while the other 10 percent is "chemically similar to natural food components" (Lecos, 1986).

The level of free radical formation occurs in a linear fashion depending on the dose. Like compounds are formed in like food products in a consistently predictable manner. The level of free radicals formed in an apple, for example, would be similar to those formed in a pear. Therefore, it is relatively easy to extrapolate data obtained from one food to another food of similar composition. If one food is determined to be safe at a certain dose then another food of similar composition can also be assumed to be as safe at the same dose (Zurer, 1986). This concept formed the basis of the new FDA regulations implemented in 1985.

While these radiolytic compounds are only formed in minute concentrations of a few parts per million, there is still concern about the long-term effects of consuming free radicals. Numerous studies have been conducted since the 1950s in which animals were fed large quantities of the compounds in question. Test animals included mice, hamsters, rats, dogs, monkeys, and rabbits. Unfortunately most of these studies did

not work well because test animals were fed very unbalanced diets. This made it difficult to determine which effects on the animals were caused by the irradiated food and which were caused by poor nutrition.

In 1980 the FDA concluded that nearly all of the early studies should be disregarded and began evaluating the safety of only the radiolytic products themselves. This new approach resulted in the FDA concluding that animal feeding studies were no longer necessary for foods irradiated at doses under 1 kGy (100 krads) because the type and amounts of free radicals formed are such that the irradiated food is as safe and nutritious as unirradiated food (Zurer, 1986).

In arriving at the conclusion that free radicals formed in low dose irradiation are not a toxic health hazard, the FDA determined that most radiolytic products are normally present in food. These 'unique radiolytic products' (URPs) are in such small quantities that they are practically impossible to detect and considered insignificant as a health hazard. According to Dr. George Giddings, Director of Food Irradiation at Isomedix, Inc., a contract irradiation firm, free radicals "occur naturally in many foods, usually decay away before consumption, probably could not survive the digestive system, and are not inherently dangerous" (Giddings, 1987). Dr. Ari Brynjolfsson, a Physicist at the U.S. Army Natick Research and Development Center,

points out that the carcinogen benzene can be formed in foods irradiated at high levels but it also occurs naturally in many nonirradiated foods. He has stated, "There is about 2000 times more benzene in a boiled egg than is produced by irradiation" (Zurer, 1986).

Consumer protection groups want approval of irradiation delayed until more is known about the levels and safety of free radicals formed during irradiation. They claim that tests to determine the long-term effects of consuming irradiated food are not adequate or conclusive. The law requires only that research indicate with 'reasonable certainty' that a food additive will not be harmful to the consuming public under the conditions intended for use. The FDA is convinced that research conducted so far has complied with this provision of the law.

#### Cancer and Genetic Mutation

There have been a few claims that irradiated food causes cancer or genetic damage. One study conducted by the London Food Commission reported a chromosomal defect in children, monkeys, hamsters and rats fed irradiated wheat or an irradiated diet. Another U.S. government supported study indicated a link between irradiated food and tumor formations. The USDA maintains these studies did not indicate irradiation was the cause of the resulting problems. In addition, the radiation doses used were 45 to 60 times higher than the dose level

approved by the FDA (Supermarket News, 1986c). Despite FDA insistence that these types of dangers do not exist at the levels currently approved, legislation has been introduced in many state legislatures and in the Congress to prevent food irradiation from becoming a reality. A labeling requirement is one such attempt.

### Labeling

Regulations first proposed by the FDA required food treated with ionizing radiation to be prominently labeled. Consumer protection groups and congressmen opposed to irradiation insisted on the labeling requirement so that consumers could avoid such products. Individual packages of irradiated food had to be labeled with the phrase 'treated with ionizing radiation' or 'treated with gamma radiation'. Any food items irradiated in bulk had to be labeled with the phrase 'treated with radiation--do not irradiate again'.

In 1984, the FDA attempted to drop the labeling requirement from its proposed regulation but met with strong opposition from health, consumer, and antinuclear groups. Despite the fact that other food treatments such as thermal canning and chemical pesticides do not require any type of labeling, in 1986 the FDA adopted a two-year requirement to label irradiated food with the phrases 'treated with radiation' or 'treated by irradiation' and the international logo, the radura, pictured in Figure 5. If they wish, manufacturers can





Figure 5: The Radura irradiation symbol.

use a more detailed label like 'treated with radiation instead of pesticides to control insect infestation' or 'treated with radiation to prevent spoilage'. Whether or not the labeling requirement will be extended beyond the current two year period remains to be seen, but in light of the controversial nature of irradiation, it seems likely.

#### Radiation Hazards

While irradiated food is not itself radioactive, fears of radioactivity are one of the primary reasons irradiation has been such a controversial issue. Many opponents of irradiation warn of the risk to plant workers and to the general public posed by irradiation facilities and the transportation of fuel for these facilities. Despite the fact that the nuclear industry is one of the most highly regulated industries in the world, opponents to food irradiation do not feel the benefits are worth the increased risks.

"Irradiation is an ultrahazardous industry that is very poorly regulated even in its current limited state," according to Robert Alvarez, director of the Environmental Policy Institute. He further states that "Allowing food irradiation will result in a quantum jump in the amounts of intensely radioactive materials circulating in society and through communities" (Zurer, 1986). Actually, the increase in transported radioactive fuel or radioactive waste material requiring

disposal, above that already used by hospitals, laboratories, and industry, is not expected to be significant. Nuclear fuel has an extended life and can be reprocessed to extend its useful life (Morrison and Roberts, 1986).

While some degree of risk of nuclear accidents or terrorist acts may exist to the food irradiation industry, continuing safety improvements will help reduce these risks in the future. One such improvement is in linear accelerator technology. Traditional linear accelerators used to irradiate food generated an electron beam with a penetrating power limited to a few inches. New versions of the linear accelerator direct the electron beam onto a metal converter plate which changes the electron beam into X-rays. X-rays can penetrate food much more deeply and approach the effectiveness of gamma radiation (Mock, 1985).

Linear accelerators offer two significant advantages over gamma radiation sources. First, when not in use they can be turned off, reducing the danger of radiation. Second, since the energy produced is machine driven, there is no radioactive source to transport or protect and no leftover radioactive waste needing disposal. "The future is in linear accelerators." envisions Dr. Ari Brynjolfsson of Natick Labs (Brynjolfsson, 1987).

## THE FUTURE OF FOOD IRRADIATION

What does the future hold for food irradiation?

The banning of dangerous chemical fumigants and preservatives and the rising costs of other methods of food preservation may quickly make food irradiation a viable and economical alternative to other food processes.

The use of irradiation in food processing is anticipated to grow very slowly. A big unknown is whether the American consumer will buy irradiated food when it becomes more readily available. It is likely that irradiation will be used only where market conditions are conducive to its acceptance, such as when production costs make it more practical and cost efficient than other methods of food preservation. One benefit of irradiation is its minimal cost, which is currently estimated by researchers to be 0.2 to 8.5 cents per pound (Morrison, 1986). Irradiation may also be used when the threat of foodborne illness demands a more effective method of food processing. The growing danger of salmonella and campylobacter in poultry should bring about the commercial irradiation of poultry products within the next few years.

The banning of ethylene dibromide (EDB) has already made irradiation a viable option for papaya growers in Hawaii. Their product must be treated before shipment

to the mainland U.S. to control fruit fly infestation. Hot water baths currently used to replace chemical fumigants have not proved to be a satisfactory substitute. As a result, Hawaii is expected to have a commercial irradiation facility in operation within a year or two (Zurer, 1986).

Irradiation will continue to be used on products such as spices, dehydrated onion, and garlic powders. These products are better preserved by irradiation than other processing methods. They also make up a very small component of the typical consumers diet and therefore pose no significant health threat.

Getting consumers to buy irradiated foods will probably remain the most difficult challenge to the irradiation industry. According to Harry C. Mussman, Executive Vice President of the National Food Processors Association, "Consumer education will be the key" (Supermarket News, 1986a). Once consumers understand the process and look at the alternatives, irradiated food may become very popular. When faced with a choice of produce treated with pesticides or produce that is radiated and pesticide-free, "The public may decide it's better to have irradiated food than chemically treated food", points out Jane Robinson, Director of the Division of Consumer Services for the Florida Department of Agriculture (Supermarket News, 1986b).

## SUMMARY AND CONCLUSION

In nearly forty years of intensive research and testing of irradiation, there has been no conclusive evidence that foods irradiated at low doses are dangerous to consumers. Neither has it been proven that irradiation is any more harmful than other forms of food preparation or processing, like thermal canning, barbecuing, French-frying, or microwaving. Chemical changes and compounds produced by irradiation, such as free radicals, are not particularly unique to irradiated products. They are naturally occurring substances found in quantities even smaller than those produced during normal heating.

Irradiation is not appropriate for every food product. It works better with some than with others. As research and new techniques are applied, the list of products that can be successfully irradiated is sure to grow. Irradiation can provide consumers with flavorful, appetizing and nutritious products. It can prevent insect infestation, delay ripening of produce, inhibit sprouting in tubers, and prevent food spoilage by killing harmful microbes and preventing the formation of dangerous toxins.

The education of consumers will be the key to making food irradiation an acceptable food preservation process. Heating and microwaving are both commonly

accepted uses of different types of radiation. A concentrated education program by the appliance industry was largely responsible for consumer acceptance of microwave cooking. But on the food irradiation issue, neither government nor the food industry has been willing to take a leading role in the consumer education process. Too many people are afraid of anything connected with radiation. Meanwhile, a loud and vocal anti-nuclear movement presents a one-sided, alarmist point of view.

Irradiation has been accepted in many non-food applications such as medical supply sterilization, permanent pressing of textiles, and sterilization of wire and cable insulation. Irradiation has numerous applications in the plastics industry. It is used in vulcanized sheet rubber, and plastic food wraps. Irradiation is even being considered for disinfecting sewage sludge. Consumers have drawn the line at eating anything irradiated.

Acceptance of irradiation as a food process may take many years, but someday it will be as accepted as canning is today (Brynjolfsson, 1987; Giddings, 1987). There will be a gradual and ongoing process of change leading to eventual consumer acceptance. "Irradiation will find a few small niches immediately," maintains Dr. Richard L. Hall, Vice President for Science and Technology of McCormick and Company, and additional

growth "...will occur gradually where advantages of cost, quality, or occasionally safety, become so clear cut they motivate change." Dr. Hall predicts that, "Ten years from now, the few who think about it will wonder why so little took so long, and what the fuss was all about" (Hall, 1984). "Food irradiation", according to Dr. Giddings of Isomedix, "is absolutely inevitable" (Giddings, 1987).



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